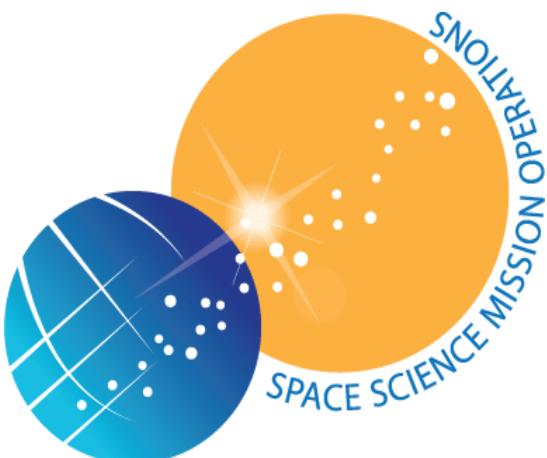




# The Virtualized Multi-Mission Operations Center (vMMOC) and its Cloud Services



## Presented by

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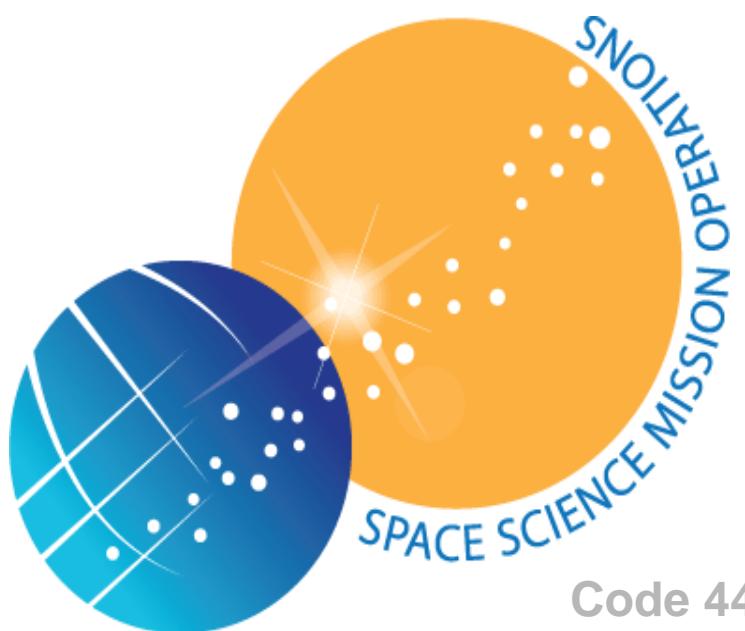
# Objective of Presentation



- **What is Space Science Mission Operations (SSMO)?**
- **What is the vMMOC?**
- **Available vMMOC Services**
- **“Looking Beyond the Horizon”**



## What is Space Science Mission Operations (SSMO)?



**Goddard**  
SPACE FLIGHT CENTER



# What is Space Science Mission Operations (SSMO)?



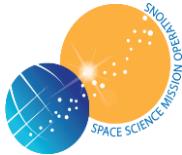
- **SSMO** provides project oversight for 19 NASA space science missions for which GSFC is responsible
- **SSMO** has a diverse set of missions:
  - heritage/launch date
  - orbit regime
  - spacecraft bus type
  - mission profile
  - communication networks
  - In-house and Out of House Mission Operations Centers (MOCs)



# SSMO Spacecraft in Operations



Mission	Launch Year	MOC Location	Science Type	# s/c	Orbit Regime	Catalog #
<a href="#">ACE</a>	1997	GSFC	Heliophysics	1	L1	N/A
<a href="#">AIM</a>	2007	LASP	Heliophysics	1	LEO	31304
<a href="#">ARTEMIS*</a>	2007	UC Berkeley	Heliophysics	2	P1, lunar orbit; P2, Lunar Lagrange Point 1	30581, 30582
<a href="#">Fermi</a>	2008	GSFC	Astrophysics	1	LEO	33053
<a href="#">IBEX</a>	2008	Orbital	Heliophysics	1	HEO (T = 9 days)	33401
<a href="#">IRIS</a>	2013	ARC	Heliophysics	1	LEO	
<a href="#">LRO</a>	2009	GSFC	Planetary (Lunar)	1	Lunar Orbit	N/A
<a href="#">MAVEN</a>	2013	LM - Denver	Planetary	1	Mars Orbit	N/A
<a href="#">MMS</a>	2015	GSFC	Heliophysics	4	HEO	40482, 40483, 40484, 40485
<a href="#">OSIRIS-REx</a>	2016	LM-Denver	Planetary	1	Heliocentric	N/A
<a href="#">Van Allen Probes (RBSP)</a>	2012	APL	Heliophysics	2	HEO	38752, 38753
<a href="#">RHESSI</a>	2002	UC Berkeley	Heliophysics	1	LEO	27370
<a href="#">SDO</a>	2010	GSFC	Heliophysics	1	GEO	36395
<a href="#">SOHO**</a>	1995	GSFC	Heliophysics	1	L1	n/a
<a href="#">STEREO</a>	2006	APL	Heliophysics	2	Heliocentric	n/a
<a href="#">Swift</a>	2004	Penn State	Astrophysics	1	LEO	28485
<a href="#">THEMIS</a>	2007	UC Berkeley	Heliophysics	3	HEO	305880, 30584, 30585
<a href="#">TIMED</a>	2001	APL	Heliophysics	1	LEO	26998
<a href="#">WIND</a>	1994	GSFC	Heliophysics	1	L1	n/a



# What is the virtualized Multi-Mission Operations Center (vMMOC)?

*The vMMOC's Objectives are ...*

- *Rapid and efficient provisioning and orchestration of spacecraft mission operation environments.*
- *Break the barrier to mission operations and enhance accessibility*



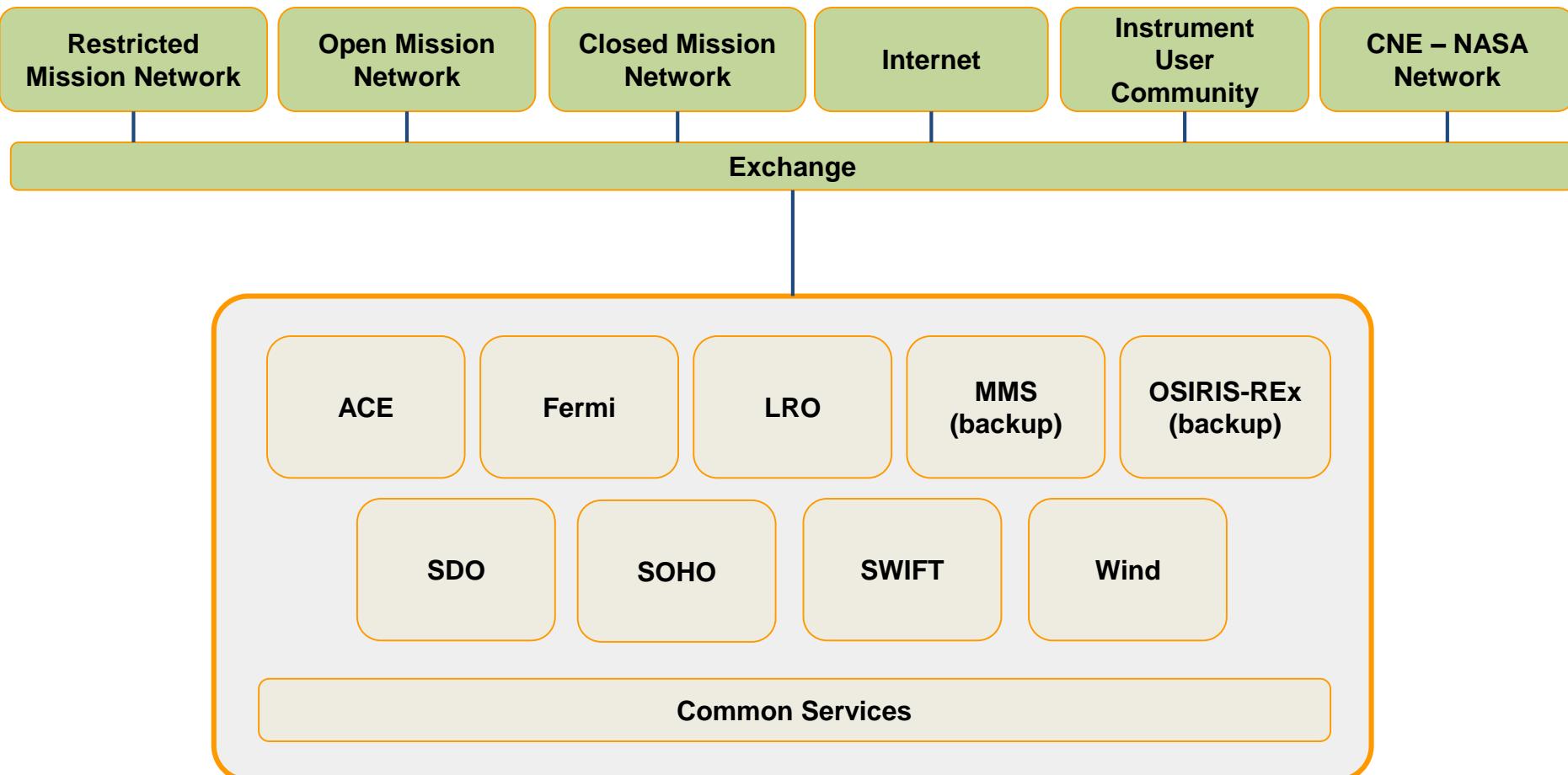
## What is the vMMOC?



- **Multiple-missions Operated from one center**
- **Local virtualized infrastructure**
- **Access to a secure public cloud computing infrastructure**
- **Situational Awareness Dashboard (a SaaS)**
- **Telemetry as a Service (TaaS)**
  - **Soon to be *Telemetry, and Tracking as a Service (TTaaS)***
- **Navigation as a Service (NaaS)**



# vMMOC's High Level Infrastructure





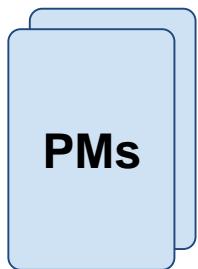
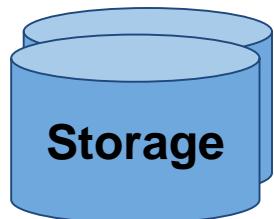
## What is the vMMOC?



- **Shared:**
  - Infrastructure
  - Product formats
  - Networking interfaces
  - Workflows & Procedures
  - Security implementations
  - Hardware and software
  - Core staff
  - Lessons-learned
  - Culture

## Private virtualized infrastructure

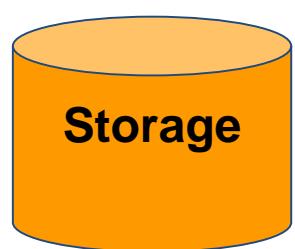
### GSFC - SSMO



Data Producers & Consumers

## Public Cloud Computing (secured)

### AWS GovCloud





## *Situational Awareness Dashboard*



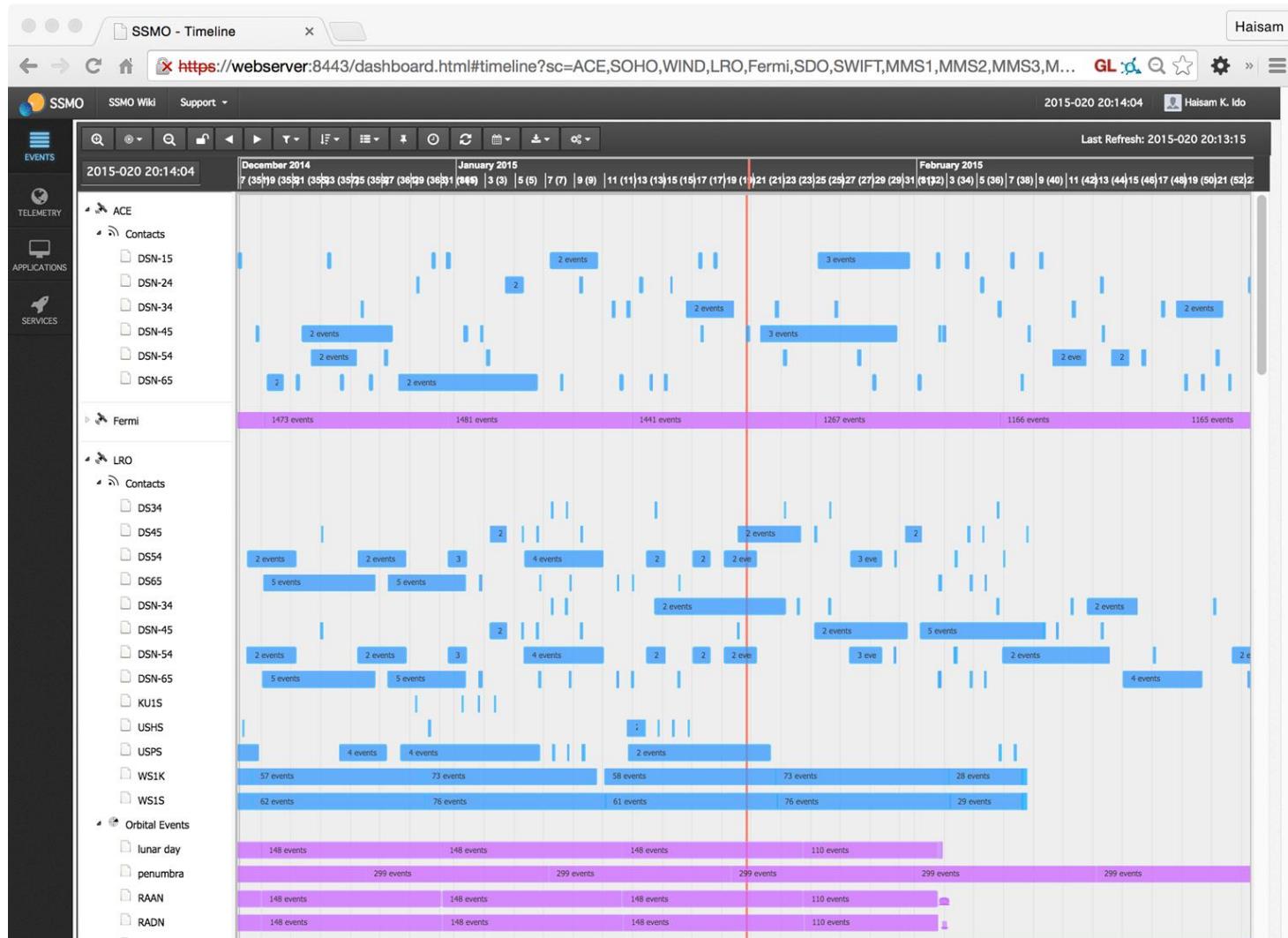
**Break the barrier to data access**



- **Provide local and remote users an integrated, situational awareness dashboard of major spacecraft and ground events**
  - Secure
  - Tailorable, self-service capability to access all spacecraft timelines
  - Liberate the data
  - Empower each engineer to tailor requests for any SSMO spacecraft
- **A web service based on NIST's Software as a Service (SaaS) model**

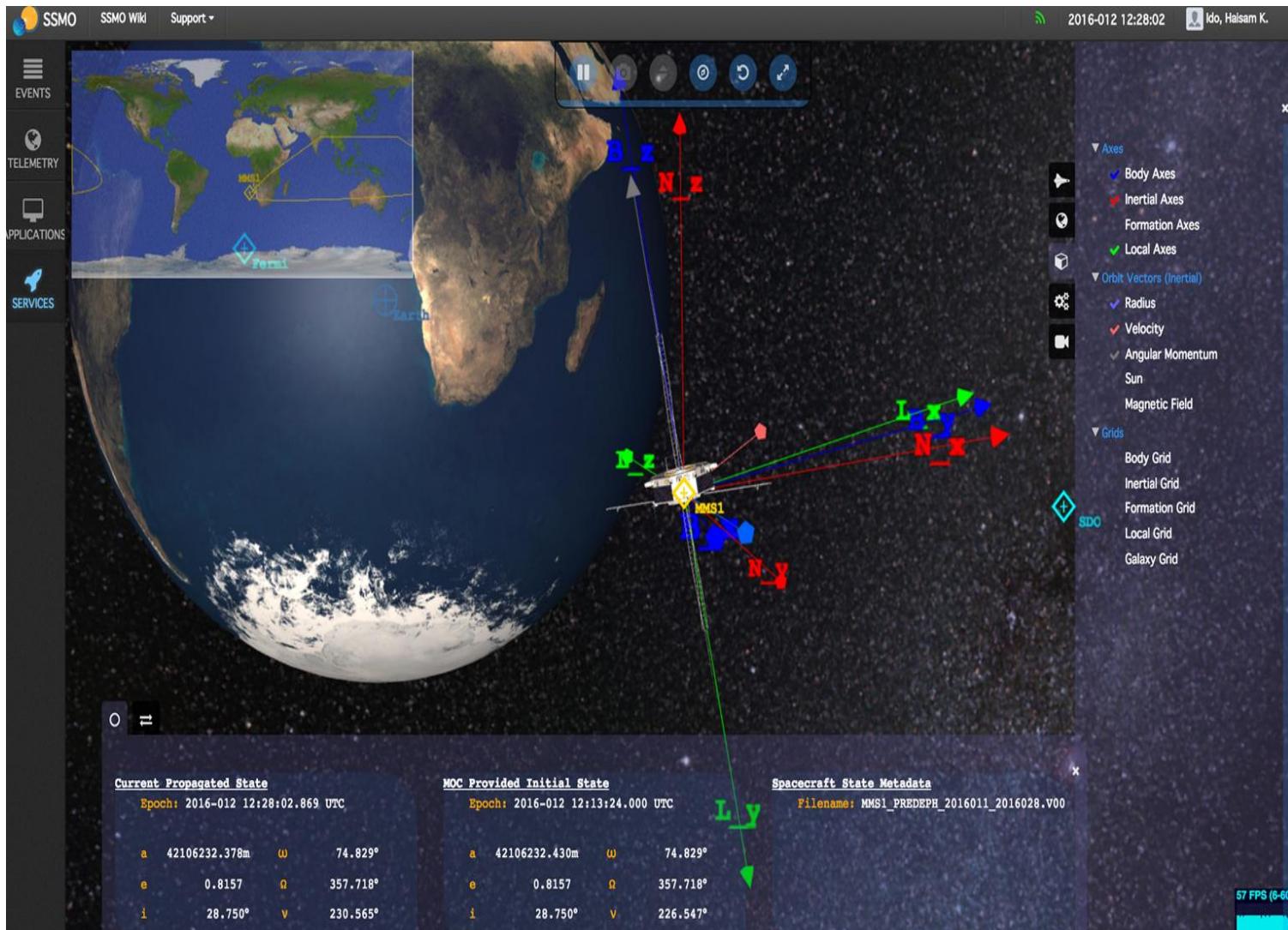


## A timeline view of ACE, Fermi and LRO



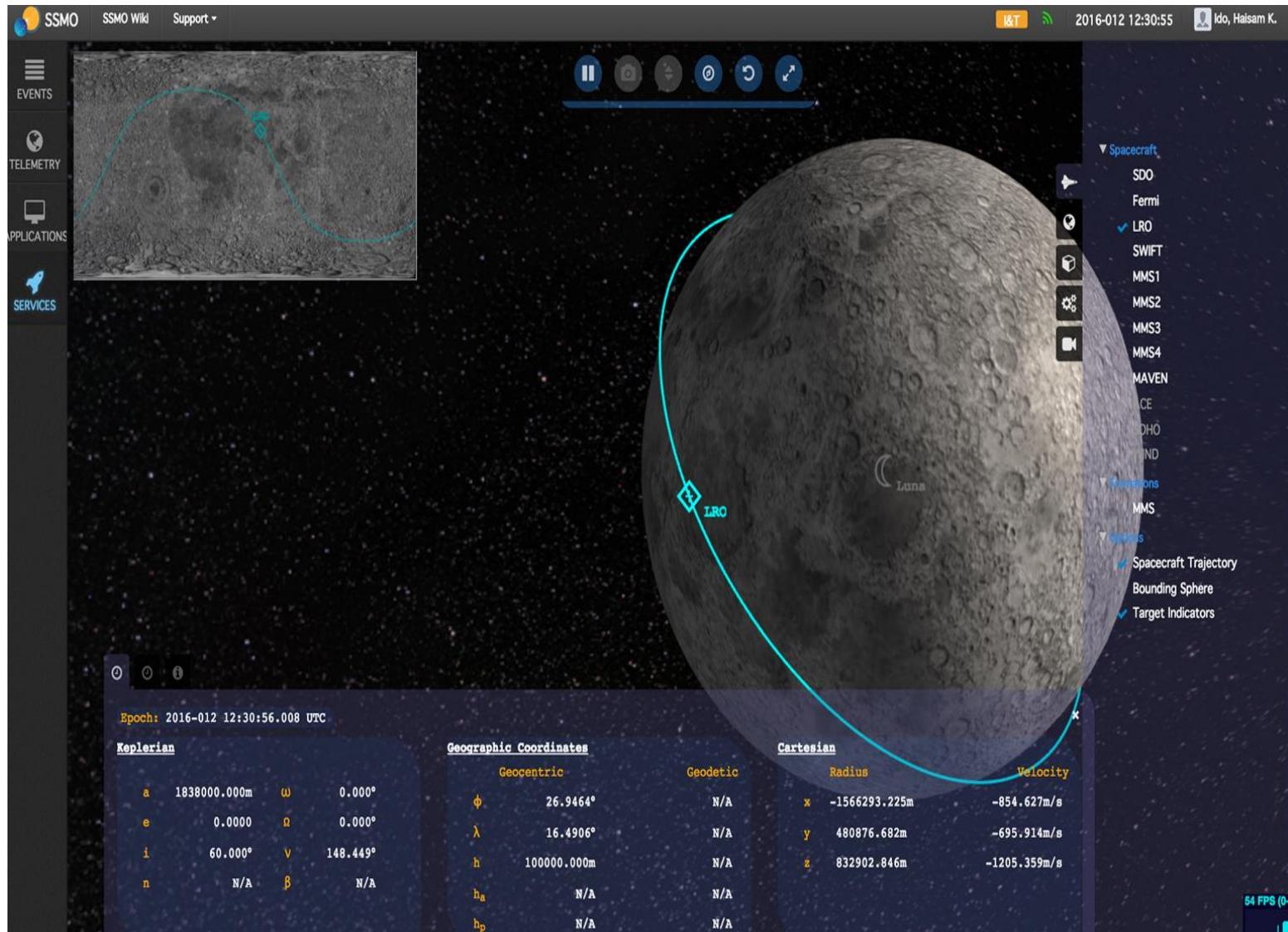


## A view of a closeup of MMS1





## A view of LRO





## Execute General Mission Analysis Tool (GMAT) in the cloud

Screenshot of the SSMO - VFS Editor interface showing the execution of a GMAT script.

**File Path:** SSMO - VFS Editor > Ex\_HohmannTransfer.script

**Script Content:**

```
1 % Script Mission - Hohmann Transfer Example
2 %
3 % This script demonstrates how to target a Hohmann Transfer
4
5
6 %----- Spacecraft
7 %
8 %
9
10 Create Spacecraft DefaultSC;
11 GMAT DefaultSC.DateFormat = 'J2000';
12 GMAT DefaultSC.Epoch = '2015-01-01T00:00:00';
13 GMAT DefaultSC.CoordinateSystem = 'EarthMJ2000Eq';
14 GMAT DefaultSC.DisplayStateType = 'Cartesian';
15 GMAT DefaultSC.X = 7100;
16 GMAT DefaultSC.Y = 0;
17 GMAT DefaultSC.Z = 1300;
18 GMAT DefaultSC.R = 0;
19 GMAT DefaultSC.VY = -1.35;
20 GMAT DefaultSC.VZ = 1;
21 GMAT DefaultSC.DryMass = 850;
22 GMAT DefaultSC.Cd = 2.2;
23 GMAT DefaultSC.Cr = 1.8;
24 GMAT DefaultSC.Cm = 15;
25 GMAT DefaultSC.SIPKern = 1;
26 GMAT DefaultSC.NAIFId = -123456789;
27 GMAT DefaultSC.NAIFIdReferenceframe = -123456789;
28 GMAT DefaultSC.Id = 'SatId';
29 GMAT DefaultSC.Attitude = 'CoordinateSystemFixed';
30 GMAT DefaultSC.ModelId = 'data/vehicle/models/aura.3ds';
31 GMAT DefaultSC.ModelOffsetX = 0;
32 GMAT DefaultSC.ModelOffsetY = 0;
33 GMAT DefaultSC.ModelOffsetZ = 0;
34 GMAT DefaultSC.ModelRotationX = 0;
35 GMAT DefaultSC.ModelRotationY = 0;
36 GMAT DefaultSC.ModelRotationZ = 0;
37 GMAT DefaultSC.ModelScale = 1;
38 GMAT DefaultSC.AttitudeDisplayStateType = 'Quaternion';
39 GMAT DefaultSC.AttitudeRateDisplayStateType = 'AngularVelocity';
40 GMAT DefaultSC.AttitudeCoordinateSystem = 'EarthMJ2000Eq';
41
42 %----- ForceModels and Propagators
43 %
44 %
45 Create ForceModel DefaultProp_ForceModel;
46 GMAT DefaultProp_ForceModel.CentralBody = 'Earth';
47 GMAT DefaultProp_ForceModel.PlanetMasses = '{Earth}';
48 GMAT DefaultProp_ForceModel.GravityModel = 'J2';
49 GMAT DefaultProp_ForceModel.GRP = 'Off';
50 GMAT DefaultProp_ForceModel.RelativisticCorrection = 'Off';
51 GMAT DefaultProp_ForceModel.ErrorControl = 'RSSStep';
52 GMAT DefaultProp_ForceModel.ErrorControl = 'RSSStep';
53
54 %----- Propagators
55 %
56 %
57
```

**Output:** #GMATCloud Execution Started

```
*****
*** GMAT Console Application
*****
General Mission Analysis Tool
Console Based Version
Build Date: May 21 2014 11:27:50

Moderator is creating core engine...
./../../../../GLOBAL$applications/gmat/plugins/lib
```

**Errors:**

```
Execution of "Ex_HohmannTransfer.script" has completed. (click to hide)
```



# *Telemetry as a Service (TaaS)*



**Break the barrier to data access**



- **Provide local & remote users access to *telemetry & tracking***
  - Secure
  - Tailorable, self-service capability to access all SSMO spacecraft telemetry & tracking:
  - Liberate the data
  - Empower each engineer to tailor requests for any SSMO spacecraft
  - Each engineer can perform analysis without interfering with operations workflows
- **A web service based on NIST's Software as a Service (SaaS) model**



## A view of the portal

2017-019-00:00:00 2017-022-00:00:00 UTC

6 WORKSPACE SEARCH GRAPH

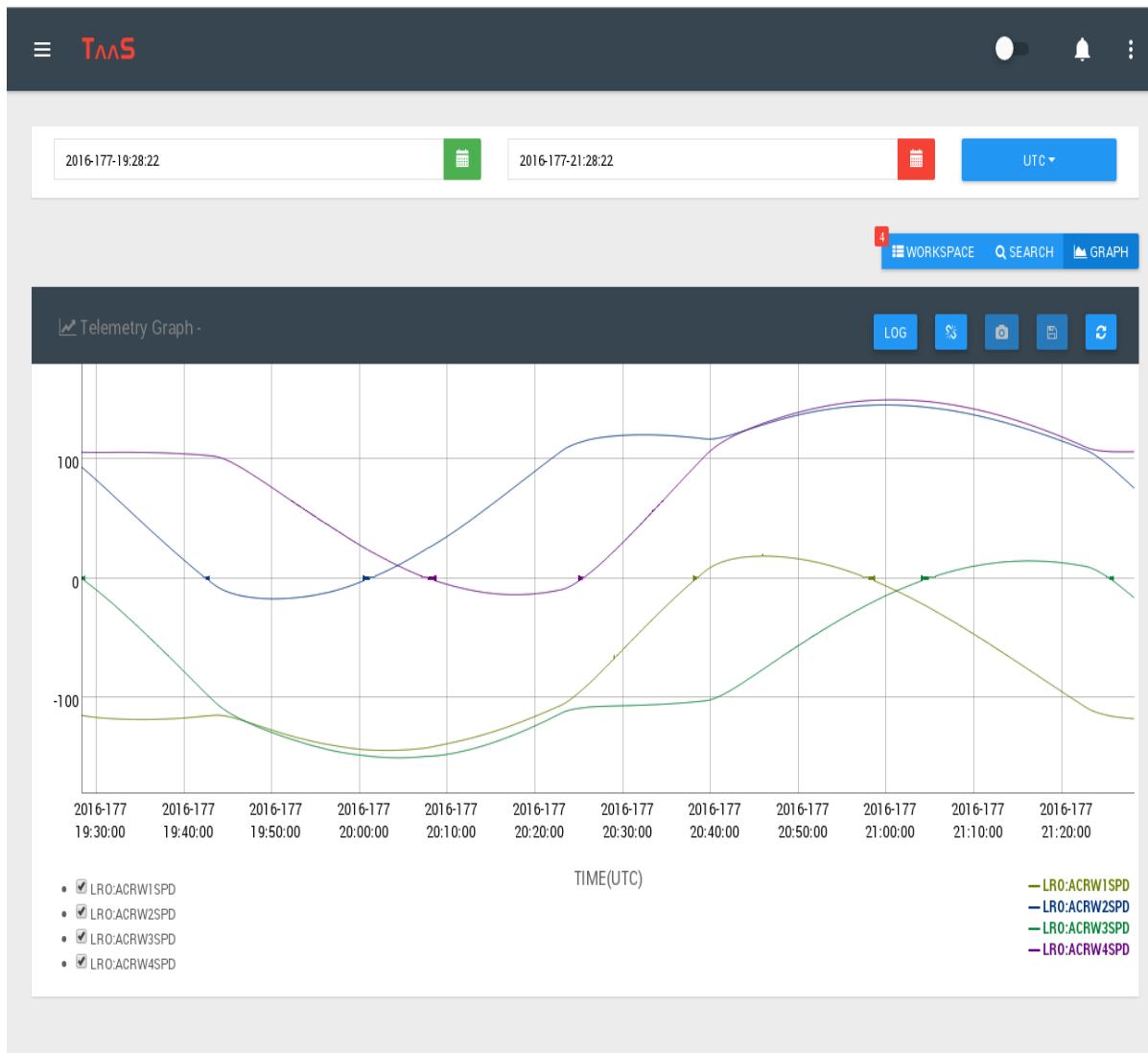
Selected Mnemonics

SPACECRAFT	PACKET	MNEMONIC	MNEMONIC DESCRIPTION	Θ	CVT ▾			
<input type="checkbox"/>								
<input checked="" type="checkbox"/>	Fermi	11	SAC_MODE	GNC_TLM_MODE Telemetry (SIANCILLARY GNC_MODE). Current spacecraft ACS mode				
<input checked="" type="checkbox"/>	LRO	203	ACRW1SPD	Reaction Wheel 1 Wheel Speed				
<input checked="" type="checkbox"/>	MMS1	126	PSE_BATV	'PSE_PMC0_BATT_V' BATTERY MODULE ANALOG BATTERY VOLTAGE ; P306,8 pwr rtn to chs(+) 23 chs to pwr rtn(-)				
<input checked="" type="checkbox"/>	SDO	138	ACS_P_DIAG[1]	Kalman Filter covariance diagonal element 1,2,3,4,5,6.				
<input checked="" type="checkbox"/>	Swift	16	SAC_MODE	ACS_TLM_MODE Telemetry. Current spacecraft ACS mode				
<input checked="" type="checkbox"/>	Swift	16	SAC_MODE	ACS_TLM_MODE Telemetry. Current spacecraft ACS mode		UNCVT ▾		

10 25 50 100



## A view of a plot of wheel speeds





# *Navigation as a Service (NaaS)*



**Break the barrier to data access**



## Navigate the Spacecraft in Support of Mission Operations

### Navigation Services

- Maneuver planning
- Maneuver execution
- Maneuver reconstruction
- Orbit estimation & control
- Attitude estimation & control

### Scheduling & Planning in Support of Navigation

- Maneuvers
- Network Availability
- Antenna Availability
- AOS/LOS
- Shadows
- Interference
- Tracking



## ***“Looking Beyond the Horizon”***



## How would one simulate hundreds of spacecraft?



- **With the coming age of OneWeb, and other massive spacecraft operations proposals, how does one:**
  - Design, Model and Simulate Ground and Space Segments ?
  - **Leverage Cloud Computing & Create Service Models, such as:**
    - Spacecraft as a Service (SCaaS)
    - Flight Software as a Service (FSWaaS)
    - Ground Segment as a Service (GSaaS)
    - Auto Provision, Orchestrate & Terminate services at will



**Thank you.**

**Any Questions?**